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Civil Engineering Department

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CVG2132 – FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING

Homework 4: Professor: Rob Delatolla

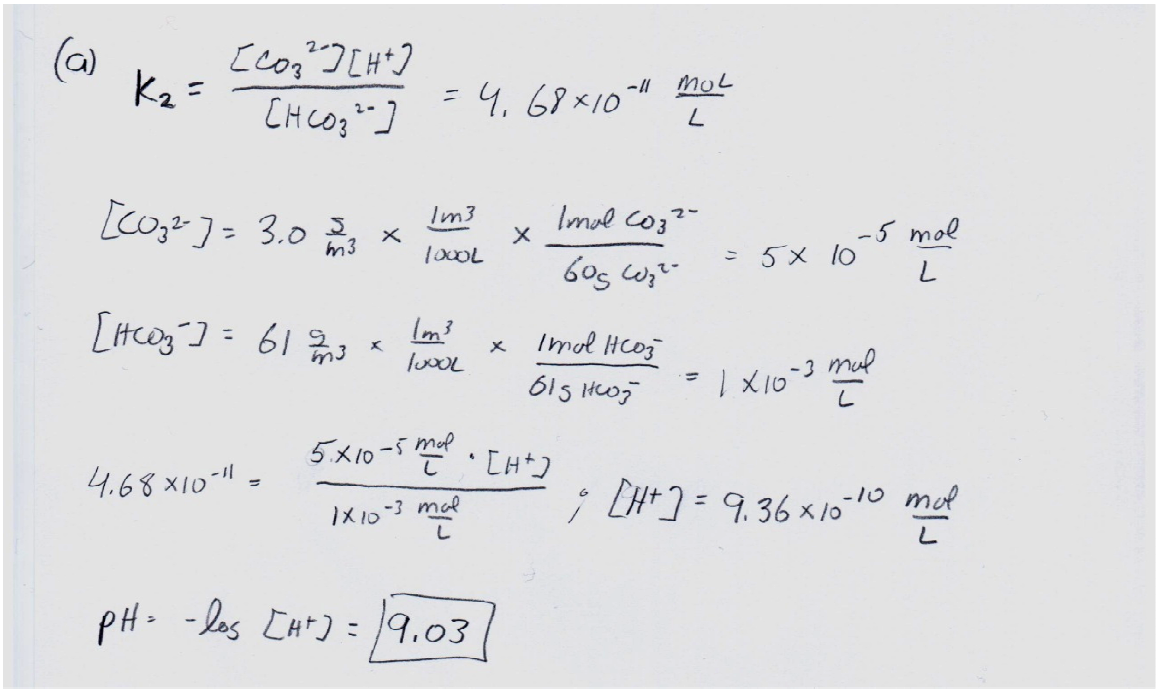
Due Date: Nov. 21, 2011 (4:00pm) – Cubby « CVG 2132 », Mezzanine A (0.5) CBY

Question 1: The lab analysis of a water sample is as follows:

Substance	g/m^3
Ca^{2+}	2.0
Mg^{2+}	85.0
Na^{+}	92.0
K^{+}	39.1
HCO_3^{-}	61.0
Cl^{-}	284.0
CO_3^{2-}	3.0
SO_4^{2-}	288.0

a) Calculate the pH of the water if the temperature is 25^{o}C.

Note at 25^{o}C, $K_2 = 4.68 \times 10^{-11}$ mol/L = $[CO_3^{2-}][H^+]/[HCO_3^-]$



(a) $K_2 = \frac{[CO_3^{2-}][H^+]}{[HCO_3^-]} = 4.68 \times 10^{-11}\ \frac{mol}{L}$

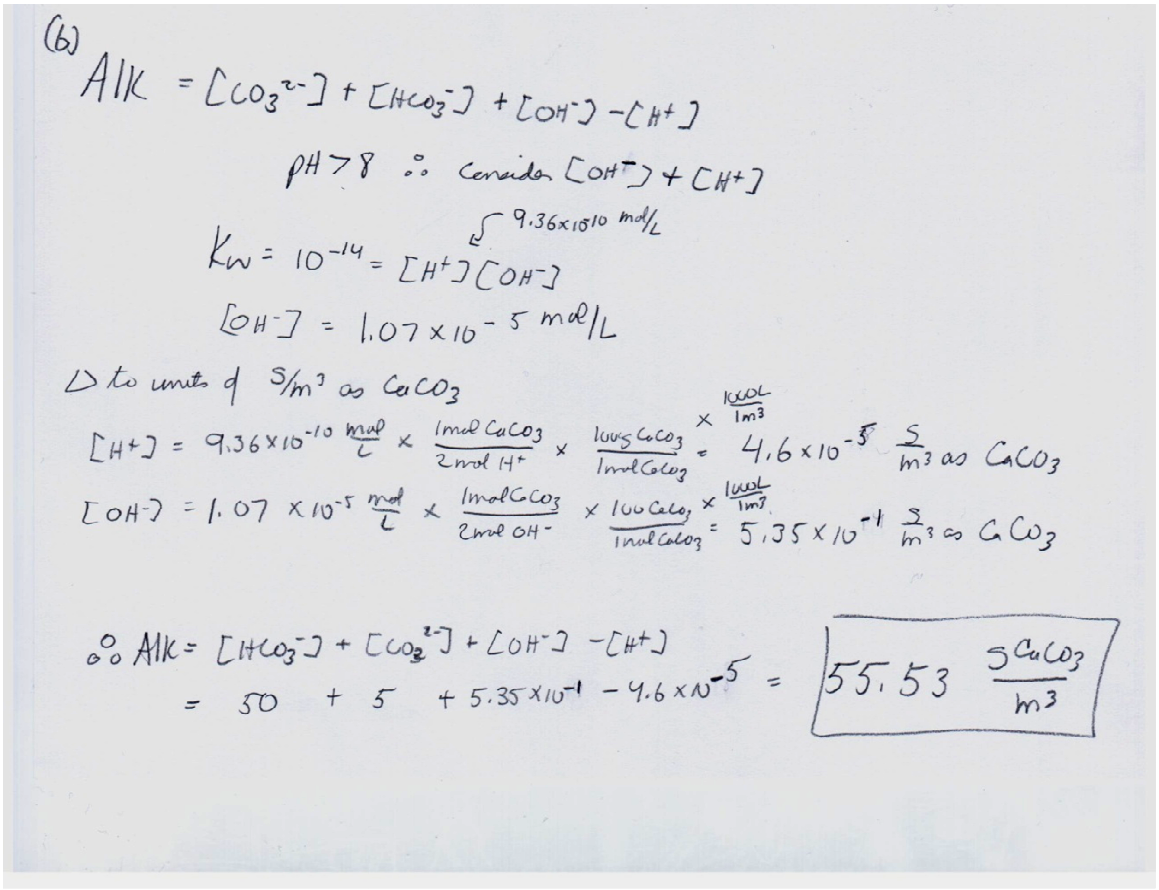
$[CO_3^{2-}] = 3.0\ \frac{g}{m^3} \times \frac{1m^3}{1000L} \times \frac{1mol\ CO_3^{2-}}{60g\ CO_3^{2-}} = 5 \times 10^{-5}\ \frac{mol}{L}$

$[HCO_3^-] = 61\ \frac{g}{m^3} \times \frac{1m^3}{1000L} \times \frac{1mol\ HCO_3^-}{61g\ HCO_3^-} = 1 \times 10^{-3}\ \frac{mol}{L}$

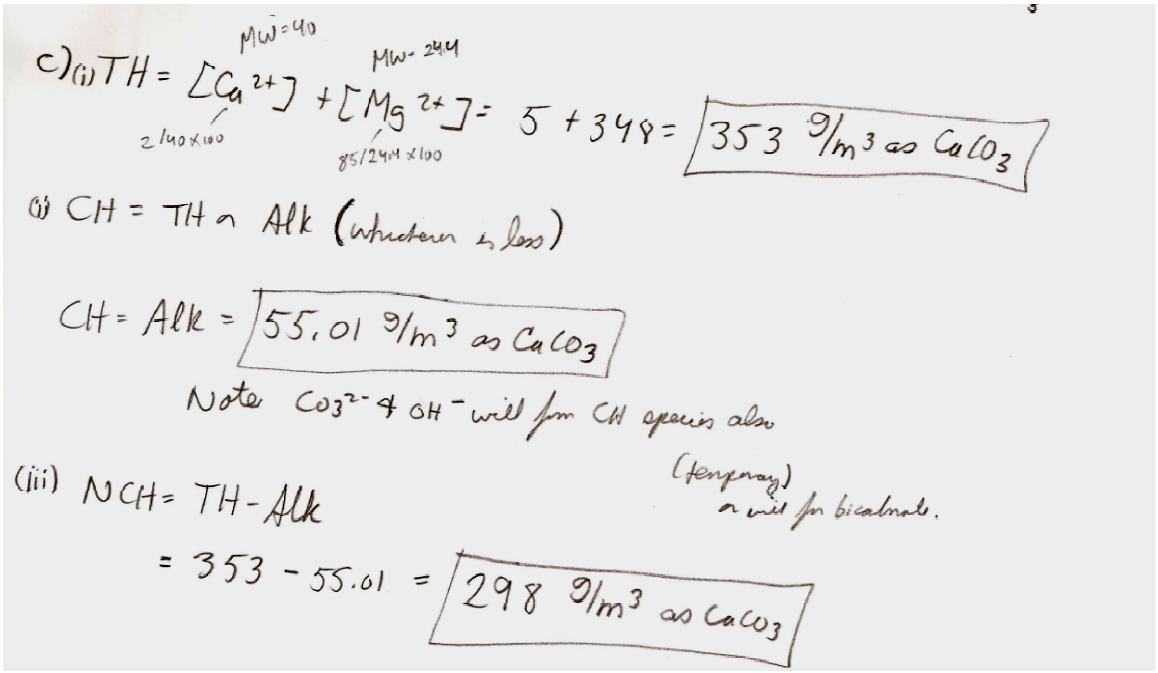
$4.68 \times 10^{-11} = \frac{5 \times 10^{-5}\ \frac{mol}{L} \cdot [H^+]}{1 \times 10^{-3}\ \frac{mol}{L}}$; $[H^+] = 9.36 \times 10^{-10}\ \frac{mol}{L}$

$pH = -\log [H^+] = \boxed{9.03}$

b) Calculate the alkalinity in terms of g/m^3 as $CaCO_3$.



c) Calculate the total hardness, carbonate hardness and non-carbonate hardness



Question 2: A water sample analysis is shown in the table below.

Compounds	Conc. (g/m^3)	Conc. ($g\ CaCO_3/m^3$)
Ca^{2+}	104	260.0
Mg^{2+}	37	151.6
Na^{+}	4	8.7
K^{+}	18	23.1
HCO_3^{-}	200	163.9
SO_4^{2-}	?	165.4
Cl^{-}	81	114.1
CO_2	13	29.5

- **The pH = 6.8.**

a) Calculate the concentration of all the compounds in the table above (except for SO_4^{2-}) in terms of g $CaCO_3/m^3$.

See solutions in table above.

b) Calculate the concentration of SO_4^{2-} as g $CaCO_3/m^3$ and mg/L of SO_4^{2-}. Assume that all constituents are accurately measured in the table above and no cations or anions were left unmeasured.

Use electron balance to solve for the concentration of SO_4^{2-}.

SUM as CATIONS as g $CaCO_3/m^3$= SUM of ANIONS as g $CaCO_3/m^3$

$(260.0 + 151.6 + 8.7 + 23.1) = (163.9 + 114.1) + [SO_4^{2-}]$

$443.4 = 278 + [SO_4^{2-}]$

$[SO_4^{2-}]$ = **164.4 g $CaCO_3/m^3$**

165.4 g $CaCO_3/m^3$ x 1 mol $CaCO_3$ /100 g $CaCO_3$ x 1 mol SO_4^{2-} / 1 mol $CaCO_3$ x 96 g SO_4^{2-} / 1 mol SO_4^{2-} = **158.8 mg/L**

c) Determine the following characteristics of the water in units of mg/L as $CaCO_3$: (i) total hardness, (ii) carbonate hardness, (iii) non-carbonate hardness, and (iv) alkalinity.

(i) $TH = Ca^{2+} + Mg^{2+} = 260 + 151.6 =$ **411.6 $\frac{g}{m^3}$ or $\frac{mg}{L}$ as $CaCO_3$** 2

(iv) $Alk = HCO_3^- =$ **163.9 $\frac{mg}{L}$ as $CaCO_3$** 2

$[HCO_3^-] + [CO_3^{2-}] + [OH^-] + [H^+]$

(ii) $CH =$ **163.9 $\frac{mg}{L}$ as $CaCO_3$** 2

(iii) $NCH = TH - Alk = 411.6 - 163.9 =$ **247.7 $\frac{mg}{L}$ as $CaCO_3$** 2

d) The facility is to treat 30 x 10^6 L/d of water from its source using lime-soda softening. Determine the MASS FLUX OF LIME (as kg/d as CaCO3) and the MASS FLUX OF SODA (as kg/d as Na_2CO_3) required to soften the water sample to a final hardness of 110.0 mg/L $CaCO_3$.

Treatment efficiency dictates that the solubility of $CaCO_3$ and $Mg(OH)_2$ in treatment plants are such that the minimum Carbonate Hardness that can be achieved is 40 mg/L as $CaCO_3$ (solubility of $CaCO_3$ is 10 mg/L as $CaCO_3$, & the solubility of $Mg(OH)_2$ is 30 mg/L as $CaCO_3$). Excess lime required for pH adjustment and kinetics of this water = 20 mg/L as $CaCO_3$.

Lime Concentration Required:

(i) Rxn 1: CO_2: 29.5 $\frac{mg}{L}$ as $CaCO_3$ 1

(ii) Rxn 2: $Ca(HCO_3)_2$: 163.9 " " " 1

(iii) Rxn 3: $Mg(HCO_3)_2$: $\emptyset$ 1

~~[(iv) Rxn 4: Ca(NCH): (260 + 163.9) = 96.1 $\frac{mg}{L}$ as $CaCO_3$]~~

(iv) Rxn 5a: Mg(NCH): 151.6 " " " 1

(vi) excess: 20 " " " 1

(vii) min solubility: 40 " " " 1

[Lime] = 325.1 $\frac{mg}{L}$ as $CaCO_3$ 1

$325.1 \frac{mg}{L} \times 30 \times 10^6 \frac{L}{d} \times \frac{1 kg}{1000000 mg} =$ **19750 $\frac{kg\ Lime}{d}$ as $CaCO_3$**

Soda Concentration Requirement

(iv) Run 4: $Ca(NCH)$: (280 - 1639) = 96.1 $\frac{mg}{L}$ as $CaCO_3$

(ii) Run 56: $Mg(NCH)$: 151.6 " "

(iii) Requirement to meet TH = 110 $\frac{mg}{L}$ as $CaCO_3$: -(110 - 40) = 70 $\frac{mg}{L}$ as $CaCO_3$

$$[Soda] = 177.7 \frac{mg}{L} \text{ as } CaCO_3$$

$$177.7 \frac{mg}{L} \text{ as } CaCO_3 \times \frac{1 \text{ mmol } CaCO_3}{100 \text{ mg } CaCO_3} \times \frac{1 \text{ mmol } Na_2CO_3}{1 \text{ mmol } CaCO_3} \times \frac{106 \text{ mg } Na_2CO_3}{1 \text{ mmol } Na_2CO_3}$$

$$= \boxed{188.4 \frac{mg}{L} \text{ as } Na_2CO_3}$$

$$188.4 \frac{mg}{L} \text{ as } Na_2CO_3 \times 30 \times 10^6 \text{ L/d} \times \frac{1 \text{ kg}}{1000000 \text{ mg}} = \boxed{5652 \frac{\text{kg } Na_2CO_3}{d} \text{ as } Na_2CO_3}$$